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(בעברית) (Hebrew): מתקן להמרת אנרגיה תרמית לחשמלית

(באנגלית) (English): THERMAL TO ELECTRICAL ENERGY CONVERSION APPARATUS

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לשימוש הלישכה

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מתקן להמרת אנרגיה תרמית לחשמלית

THERMAL TO ELECTRICAL ENERGY CONVERSION APPARATUS

THERMAL TO ELECTRICAL ENERGY CONVERSION APPARATUS

Field of the Invention

The present invention relates to the field of energy production. More particularly, the present invention relates to an energy converter unit (hereinafter sometimes simply 'converter') for converting thermal energy into electrical energy.

Background of the Invention

Currently, the most commonly used electrical energy production technologies still make massive use of fossil fuels, which are used for generating steam. The generated steam imparts rotation of movement to a turbine, the shaft of which is mechanically coupled to a rotor of an electrical generator. Upon rotation of the rotor, electrical energy is produced, the magnitude of which is a function, among other things, of the rotation of speed of the rotor and the size of the generator. Using coal, petroleum or gas for producing electricity has several drawbacks. For example, transportation of coal and fuel is expensive and raises the final cost of the electrical energy that is produced using them. In addition, using coal and fossil fuel greatly pollutes the environment. These, and other, drawbacks encourage the development and use of other alternative technologies, and in particular technologies that are based on the exploitation of energy of wind, sea waves and solar energy.

Currently, there are technologies that exploit solar energy in two ways. The first way involves exploiting solar energy to directly heat a liquid, usually water, for, e.g., heating the interior of an apartment. According to this method, a conduit, through which the liquid (normally water) passes,

is laid in a 'heat absorbing environment' where it is exposed to the solar energy. The 'heat absorbing environment' is normally a flat black metal platform, on which the conduit is coiled to absorb as much of the solar energy as possible. Since solar systems of this kind are in broad use, no further description of will be given herein with respect to their functioning and structure. The conversion efficiency of this technology is known to be very low (usually not more than 10%).

The second way to exploit solar energy is to convert it into electricity. Direct Thermal to Electric Conversion (DTEC) technologies are known. Recent advances in thermal-to-electric conversion technologies such as thermoelectrics and thermophotovoltaics have demonstrated the potential for achieving high-efficiency, solid-state electric generators that could convert thermal energy into electricity. However, these technologies are very expensive, and they produce direct current, which is problematic because many electricity appliances use alternating current.

The efficiency, by which heat can be converted into electricity, is limited by the theoretical maximum efficiency of the Carnot cycle, which is known to be a cycle (of expansion and compression) of an idealized reversible heat engine that does work without loss of heat. Although the Carnot efficiencies drop as the temperature differences between hot and cold side decreases, the theoretical maximum conversion efficiencies can range from a low of about 40% to a high of about 77%, depending on the used thermal sources. However, current Direct Thermal to Electric Conversion (DTEC) technologies fall far short of Carnot conversion efficiencies and, in many cases, fail to exhibit sufficient power densities to meet requirements for many commercial applications.

It is a known phenomenon that a movement of an electrically conducting wire across a magnetic field induces an electric current in the wire, which depends, among other things, on the flux of the magnetic field and on the velocity of the wire. Likewise, a flow of a 'liquified' magnet inside a conduit, around which a conducting wire is coiled, can induce electric current in the wire.

In recent years, researchers have prepared ferrofluids, which have the fluid properties of a liquid and the magnetic properties of a solid. The ferrofluids contain tiny particles of a magnetic solid suspended in a liquid medium. A ferrofluid is a stable colloidal suspension of sub-domain magnetic particles in a liquid carrier. The particles, which have an average size of about 100Å (10 nm), are coated with a stabilizing dispersing agent (surfactant) which prevents particle agglomeration even when a strong magnetic field gradient is applied to the ferrofluid. A typical ferrofluid may contain (by volume) 5% magnetic solid, 10% surfactant and 85% carrier (liquid). Ferrofluids are commercially available.

A notion, as to the properties and actual and possible uses of ferrofluids may be found in the following websites:
http://mrsec.wisc.edu/edetc/ferrofluid;
http://www.physicscentral.com/action/action-03-07-print.html;
http://www.ferrotec.com/usa/ferrofluid_technology_overview.htm;
http://www.ferrotec.com/usa/domain_detection.htm; and
http://www.rare-earth-magnets.com/detail.aspx?ID=6.

When a ferrofluid surrounded by a gaseous environment is placed in a container and its temperature is its boiling temperature, the liquid portion

thereof evaporates. If this process takes place in a situation where the gas is flowing, then the magnetic particles are swept along into the gas stream. Hereinafter, by 'ferrogas' is meant hereinafter a mixture of two gases, one being the vapors of the ferrofluid and the other being the carrier gas (e.g., air or CO2), which carries the magnetic particles. By 'carrier gas' is meant herein the gaseous atmosphere initially surrounding the ferrofluid.

By 'ferromixture' is meant hereafter a combination of ferrofluid and ferrogas. Depending on the location of the magnetic particles in the converter, they may be suspended in a ferrofluid, ferrogas or ferromixture.

It is an object of the invention to provide an apparatus which utilizes the magnetic characteristics of ferrofluid to produce electric energy.

It is another object of the invention to provide an apparatus for converting thermal energy into electricity with a higher efficiency then the conversion efficiency in conventional technologies.

Other objects and advantages of the invention will become apparent as the description proceeds

Summary of the Invention

The present invention provides a ferrofluid based closed-loop energy converter (hereinafter just 'converter') for converting thermal energy into electrical energy.

By 'first temperature (T1) is meant hereinafter the instantaneous temperature of a Heat Absorbing Container (HAC), and by 'second

temperature (T2) is meant hereinafter the instantaneous temperature of a Heat Dissipating Container (HDC), which is, sometimes, referred to as 'condenser'.

By 'outlet conduit' is meant a conduit that conveys ferrogas from the outlet of the HAC to the inlet of the HDC. Under some operating conditions, and depending on the location of the ferromixture in the closed-loop converter, it might occur, that the liquid of the ferromixture turns completely into gas and the ferromagnetic particles, which are normally suspended in a liquid carrier, are no longer suspended in the liquid carrier, but, rather, they are suspended in a gas carrier. Changing the phase of the liquid of the ferrofluid to gas, and vice versa, is essential for providing the force that drives the magnetic particles in cyclic manner in the closed-loop converter.

The content of the gas in the ferromixture varies according to the temperature of the mixture and the pressure exerted thereon. An adequate quantity of gas in the ferromixture makes it compressible, to some extent, which property is utilized by this invention, as described hereinafter.

By 'inlet conduit' is meant a conduit that conveys ferrofluid from the outlet of the HDC (i.e. the condenser) to the inlet of the HAC.

By 'activated valve' is meant hereinafter a valve that is activated by use of an actuator that can be, e.g., an electro-mechanical, a mechanical or magnetic. The actuator can be operated by a mechanical controller (i.e., a mechanical synchronizer) or by an electronic controller (hereinafter referred to collectively as 'control means'), to control the activation of the valve. In case of an electronic controller, it is provided with dedicated software.

The converter of this invention is a closed system that contains, at the time of its assembling, a ferrofluid and a carrier gas (by a ratio of about 1:1). The mixture ferrofluid and carrier gas is kept at sub-atmospheric pressure, to lower and control the boiling temperature of the ferrofluid.

The converter converts thermal energy into electrical energy by causing the ferrofluid to circulate in the converter to induce electric current in coils of one or more electric wires, comprising:

a) A main, closed-loop, circuit that comprises:

a.1) A Heat Absorbing Container (HAC). The HAC has an inlet that is connected to a first end of an inlet conduit and a first outlet that is connected to a first end of an outlet conduit. The HAC has a first cross-sectional area. The HAC, inlet and outlet conduits initially containing a ferrofluid and a carrier gas. The HAC is intended to absorb heat energy from an external heat source to heat the ferrofluid and carrier

gas contained therein to a first temperature (T1) and first pressure (P1). The outlet and inlet conduits have a cross-sectional area smaller then the first cross-sectional area of the HAC;

a.2) An elongate Heat Dissipating Container (HDC), having an inlet, connected to the second end of the outlet conduit, and an outlet connected to the second end of the inlet conduit. The HDC has a second cross-sectional area smaller than the first cross-sectional area of the HAC, and the HDC is initially filled with ferrofluid and carrier gas. The HDC is intended to dissipate heat to an external heat sink to cool the ferrofluid and carrier gas contained therein to a second temperature (T2), lower than T1, and a second pressure (P2). The ferrofluid in the HAC passes to the HDC, through the outlet conduit, in the form of ferrogas whenever P1 equals a predetermined value higher than P2, and the ferrogas carries magnetic particles from the HAC to the HDC in the first step of the operational cycle of the converter. The ferrogas gradually condenses, while passing through the elongate HDC, until at the outlet of the HDC, it essentially condenses to be entirely ferrofluid. The ferrofluid is returned from the HDC to the HAC to complete a second step of the cycle and the entire cycle;

b) A reservoir container, connected by a conduit to the outlet of the HDC, for regulating the operating conditions in the converter such that the relationship between T1 and P1 assures that the ferrofluid remains in the liquefied phase inside the HAC and changes from

ferrofluid to ferrogas while passing from the HAC to the outlet conduit, and such that the relationship between T2 and P2 assures full condensation of the ferrogas at the outlet of the HDC, by allowing exchange of ferrofluid, which is stored in the reservoir container, with the main circuit such as to lower, or to raise, as required, the overall pressure in the main circuit. The reservoir container is utilized also for further cooling, in each cycle of operation of the converter, the ferrofluid at the outlet of said HDC, by releasing colder ferrofluid towards the outlet of the HDC;

c) Activated valves, for timely opening and closing the first outlet of the HAC and the outlet of the HDC and inlet/outlet of the reservoir container;

d) A first mechanical one-way valve, connected at the inlet of the HAC, for allowing ferrofluid to flow only in a direction from the outlet of the HDC to the inlet of the HAC, as a result of a pressure exerted thereon by the flow of ferrofluid, and a second mechanically activated one-way valve, connected at the inlet of the HDC for allowing ferrogas to flow only in a direction from the first outlet of the HAC to the inlet of the HDC, as a result of a pressure exerted thereon by the flow of ferrogas;

e) Control means, for timely activating the valves;

f) magnetic field generation elements, for generating magnetic fields in the area of sections of the inlet and first outlet conduits to align

the magnetic particles in the sections such as to cause alignment of the magnetic fields generated by the magnetic particles while moving through the sections of the conduits; and

g) Electricity conducting wires, coiled around sections of the inlet and outlet conduits, wherein electric current is induced in the coils of the wires in response to the magnetic field generated by the moving particles.

In one embodiment, the converter further comprises a booster container and a booster conduit. The booster container comprises a booster inlet connected to a second outlet of the HAC and a booster outlet, and a first end of the booster conduit is connected to the booster outlet and a second end of the booster conduit is connected to a midsection of the HDC. The ferrofluid passes from the HAC to the booster container and it changes phase from ferrofluid to ferrogas while passing from the booster container to the booster conduit, and the ferromixture arriving at the HDC at the second end of the booster conduit boosts the flow of the ferrofluid, which exists the HDC to flow through the inlet conduit towards the HAC. The second outlet of the HAC and the booster outlet are each controlled by an activated valve that is controlled by the controller, and the midsection is provided with a mechanical one-way valve that opens as a result of the pressure exerted thereon by the ferromixture passing through the booster conduit.

In another embodiment, the HAC includes a third outlet, a "slowdown"/"shutdown" outlet, and the HDC includes a second inlet, a "slowdown"/"shutdown" inlet. The second inlet is connected to the third outlet by a "slowdown"/"shutdown" conduit, for allowing, whenever required, slowing down of a velocity of flow of the circulating ferrofluid, ferrogas and ferromixture, to maintain the velocity in a desired operating range, or, if desired, to completely stop the circulation of the ferrofluid/ferrogas/ferromixture and, thus, the operation of the converter. The slowing down and stopping are accomplished by decreasing the difference between the pressure inside the HAC (P1) and the pressure inside the HDC (P2), by opening, momentarily or continuously, respectively, the third outlet, whereby to decrease the pressure in the HAC (P1) and, thus, the velocity of the flow of the ferrogas inside the outlet conduit of the HAC and inside the booster conduit. The "slowdown"/"shutdown" outlet is controlled by an activated valve that is controlled by the controller.

The slowdown/shutdown outlet is preferably located closer to the outlet of the HAC than to its inlet, and the slowdown/shutdown inlet is preferably located closer to the outlet of the HDC than to its inlet.

In the most preferred embodiment, the HAC is divided into two longitudinal sections, A1 and A2, and the HDC is divided into two

longitudinal sections, B1 and B2, A1 and B1 being inlet sections of said HAC and HDC, respectively, whereas A2 and B2 being outlet sections of said HAC and HDC, respectively. The division of the HAC and HDC is utilized for obtaining an internal acceleration of the ferrofluid and ferromixture inside the HAC and HDC, respectively, wherein each of the two corresponding sections are connected by a mechanical one-way valve that opens as a result of force exerted thereon by flow of ferrofluid and/or ferromixture. The mechanical one-way valves allow ferrofluid and/or ferromixture to flow only in a direction which conforms to the circulation direction.

In another embodiment, the first outlet conduit of the HAC and the booster conduit are provided with an optical arrangement for collecting light rays and for focusing the collected light rays such as to raise the temperature of the ferrogas contained within the conduit. The rise in temperature causes an increase in the velocity of the magnetic particles that are suspended in the ferrogas.

In another embodiment, the optical arrangement comprises a window that is formed in the walls of the outlet and booster conduits, near the corresponding electrically activated valves.

In another embodiment, the activated valve connected to the first outlet of the HAC and the valve connected to the outlet of the booster are each

provided with an optical arrangement for collecting light rays and for focusing the collected light rays such as to raise the temperature of the ferrogas contained within the outlet conduit and the booster conduit, respectively, for increasing the velocity of the magnetic particles that are suspended in said ferrogas. The optical arrangement is arranged such that the focused light rays pass through the corresponding valve and the location of the corresponding focal point changes with the movement of the respective valve such that light rays are focused whenever the valve is in the "open" state, and dispersed otherwise.

Preferably, the window comprises an electrically activated shutter, which opens and closes when the first outlet and the booster conduit's outlet open and close.

In a preferred embodiment, the optical arrangement comprises a heliostat arrangement for allowing the optical arrangement to self-align according to the direction of the sun.

The use of an optical arrangement, as described herein, is only an option. However, the use thereof allows improving the efficiency of the converter. In cases where the difference between the temperatures, to which the HAC and the HDC are exposed, is large enough, there might be no need to utilize the aforesaid optical arrangements.

The present invention provides also a method for converting thermal energy into electrical energy by causing magnetic particles to circulate in a closed-loop circuit, which includes a HAC, elongate HDC, inlet conduit that connects the input of said HAC to the output of said HDC, and outlet conduit that connects the outlet of said HAC to the inlet of said HDC, and by utilizing the circulating magnetic particles to induce electric current in electric wires that are coiled around sections of the inlet and outlet conduits. The method comprises:

a) Absorbing heat, from an external heat source, by a HAC, which is filled with ferrofluid and carrier gas, to increase the pressure inside the HAC;
b) Commencing a first step of a cycle of operation of the converter, by permitting the high pressurized ferrofluid to pass, through an outlet conduit, towards an elongate HDC (i.e., a condenser), while changing phase in the outlet conduit from ferrofluid to ferrogas. The magnetic particles, which were originally suspended in the ferrofluid, are suspended, or carried, at this stage, by the ferrogas;
c) Completing the first step by storing the high pressurized ferrogas, in the form of ferromixture, in the HDC;
d) Commencing a second step of the cycle of operation, by utilizing the stored pressurized ferromixture to force (i.e., to 'push') already condensed steam to flow forwards as ferrofluid from the HDC back

to the HAC, while causing the ferrogas in the HDC to condense inside the HDC as it flows through the HDC, whereby to complete the second step and the entire cycle of operation of the converter;

e) Commencing a new, subsequent, cycle of operation, by repeating steps a) to d); and

f) In each cycle, aligning the magnetic particles while they pass through the sections of the inlet outlet conduit, around which electricity conducting wires are coiled, so as to cause the magnetic particles to induce electric current in the coiled electric wires. By 'uniformly' is meant arranging the magnetic particles such that their like poles (e.g., their 'north' poles) face the same direction.

More specifically, according to the present invention, ferrofluid and carrier gas that are contained within the HAC, are heated in the HAC to a first temperature (T1), whereas a ferromixture that is contained within the HDC (condenser) is cooled to a second temp (T2), lower than T1, and the difference between the T1 and T2, which corresponds to a pressure difference (P1 and P2, respectively), generates a force that causes the magnetic particles of the ferrofluid to circulate in the closed-loop converter. The flow of the magnetic particles is then utilized to induce electric current in an electricity conducting wire.

The larger is the difference between T1 and T2, the larger is the driving force and, therefore, the higher is the velocity of flow of the ferrofluid, ferrogas and ferromixture in the converter, and consequently, the stronger is the electric current that is induced in the electric wires. Additional factors, which affect the operating conditions of the converter and the efficiency thereof, are: (1) the initial sub-atmospheric pressure of the converter, which determines temperature and pressure offset values, around which the operating temperatures and pressures are set; and (2) the ratio between the ferrofluid and the carrier gas in the conveter.

Brief Description of the Drawings

In the drawings:

- Fig. 1 schematically illustrates the general layout and functionality of the converter, according to the present invention;
- Fig. 2 schematically illustrates a layout and functionality of the converter, according to a preferred embodiment of the present invention;
- Fig. 3 (prior art) schematically illustrates a sea-eave energy converter based on a wave wing; and
- Fig. 4 schematically illustrates the sea-eave energy converter with additional wind wing.

Detailed Description of Preferred Embodiments

The energy converter of the invention is basically a device capable of absorbing heat from an external heat source and producing electricity while delivering a portion of the heat to a cold temperature reservoir. The external heat source, which provides the required heat to the converter, can be essentially any heat source. For example, the heat can be provided by a nuclear power station, or from an air condition system, or a compressor or any operating engine or an electric motor. In the preferred embodiment the heat source is the surrounding environment and solar radiation. In contrast to conventional industrial power plants, the present system does not use energy consuming machinery such as compressors or pumps. The working substance of the energy converter of the invention is a ferrofluid with intrinsic magnetic properties instead of superheated steam that is usually utilized in conventional power plants to drive a turbine. The ferrofluid coexists together with its vapor in a large chamber, which absorbs heat from the external source. In order to control the boiling temperature of the ferrofluid, a non-reacting gas may be inserted into the chamber. This gas must have a very low boiling temperature so that it will always remain in gas phase. Air, for example, is an appropriate choice. The hot ferrofluid emerges from the chamber into a pipe and is vaporized while exiting the valve connecting them. The vapor contains very small magnetic particles and is at high pressure. As the particles move through the closed-loop converter, they produce in windings of an

electrical wire an electrical current. After passing through the region surrounded by the coil of wire, the vapor enters a condenser in which it is liquified at low pressure and temperature. The liquid from the condenser is then returned, passing through another coil of electric wire, to the main heating chamber.

The present invention utilizes the following phenomena:

1) When, for example in a spray paint gun, compressed air is forced to flow at a high speed through a restricted region in a pipe, the pressure of the flowing air after the restriction is reduced, allowing liquid paint is be drawn into the air stream. This phenomenon is utilized in the first step of this invention, in which the magnetic particles are carried by ferrogas from the HAC to the HDC.

2) It is known that when a gas, or a mixture of a liquid and gas, is compressed, its temperature rises. Also whenever a gas or a gaseous mixture is forced to flow from a conduit into and through a narrower conduit, its pressure increases and its temperature rises. The increase is a function, among other things, of the ratio between the cross-sectional areas of the two conduits. The opposite phenomenon occurs whenever a gas, or a mixture, moves from a conduit to a wider conduit. The present invention utilizes differences in conduit diameters to cause changes in the pressure and temperature of the ferromixture, as described in detail hereinbelow.

After filling the closed-loop converter with ferrofluid and carrier gas (i.e., at the manufacturing stage) in a ratio of about 1:1, HAC 101 inlet and outlet valves 107 and 104, respectively, HDC 102 inlet and outlet valves 105 and 106, respectively, and valve 117 are all in the "close" state to start the first step of cycle of generation of electricity as described hereinafter. The ferrofluid contained in HAC 101, in HDC 102 and in the conduits which connect them to one another (118 and 120), is caused to circulate in the closed-loop converter in the manner described hereinafter.

Fig. 1 schematically illustrates a simplified embodiment of the converter of the present invention, in order to describe the general layout and principle of operation of the converter. HAC 101, elongate HDC 102, and the conduits that connect them to form a closed-loop system, are partially filled with ferrofluid and carrier gas. Initially, the pressure of the carrier gas in the HDC is lower than atmospheric pressure, to allow boiling of the ferrofluid at lower temperatures than would have been possible at atmospheric pressure. HAC 101 and the ferrofluid and carrier gas in it absorb heat from an external source, such as the sun, to heat the ferrofluid and gas to a first temperature (T1), and, at the same time, HDC 102 dissipates heat to an external heat sink, cool the ferromixture contained therein to a second temperature (T2), lower than the first temperature.

As HAC 101 absorbs heat from the external heat source, the temperature of the ferrofluid contained therein starts to increase to a first temperature, causing the pressure inside HAC 101 (P1) to increase. At the same time, the ferrofluid is cooled in HDC 102 to a second temperature, lower than the first temperature, causing the pressure inside HDC 102 (P2) to decrease. In other words, the difference between the first and the second temperatures is translated into a corresponding difference in the pressure inside HAC 101 and HDC 102. The difference between these pressures (i.e., P1-P2) is the force that will cause the magnetic particles to circulate in the closed-loop converter as described hereinbelow.

When the pressure difference (P1-P2) reaches some predetermined threshold value, valves 104 and 105 are essentially simultaneously opened to initiate the first step of the cycle. As mentioned hereinbefore, reducing the pressure of the gas in contact with a liquid decreases the boiling temperature of the liquid. Accordingly, because the pressure in conduit 118, at this stage, is lower than the pressure in HAC 101, the liquid carrier of the ferrofluid (which was kept up till this stage - in HAC 101 - as liquid, because of the higher pressure in HAC 101), now evaporates and becomes a gaseous jet that carries magnetic particles from HAC 101 into the direction of HDC 102, along conduit 118. The gaseous jet pushes the (colder) ferrofluid and carrier gas in conduit 118 and in HDC 102 towards valves 106, 107 and 117. The gas-liquid mixture pushing against the

ferrofluid inside HDC 102 increase the pressure (P2) and temperature (T2) in HDC 102. As P2 increases, the temperature of the content of HDC 102 increases also. Simultaneously, the pressure P1 decreases, and the temperature (T1) inside HAC 101 decreases as the ferrofluid is expelled from it.

Elongate HDC 102 is designed to be sufficiently long, in the direction of the flow of the ferrogas/ferromixture/ferrofluid, such that the temperature of the mixture at its inlet is considerably higher than the temperature at its outlet. Therefore, the percentage of ferrofluid in the mixture will increase in the direction of the outlet of the HDC 102.

When P2 reaches a maximum value, valves 104 and 105 are closed, to complete thereby the first step of the cycle. Then, valves 106 and 107 are opened, and the over-pressure in HDC 102 relative to the pressure in HAC 101, pushes the condensed ferrogas through valve 106, towards HAC 101, through conduit 120. When the pressure P1 in HAC 101 reaches a maximum value, valves 106 and 107 are closed, whereby completing the second step and the entire cycle.

Now, the next cycle begins, wherein: (1) HAC 101 absorbs external heat to raise the temperature of the (now) cold ferrofluid contained therein to the first temperature (T1), and (2) HDC 102 dissipates heat to the heat sink,

lowering the temperature of the (now) hot ferrogas and ferrofluid contained therein to the second temperature (T2), and (3) operating valves 104 to 107 as described in connection with the first cycle described hereinabove. Unless converter 100 malfunctions or it is necessary for some reason, to halt the operation of the converter, one cycle will follow another cycle with, at each cycle, some portion (i.e., a 'batch') of the ferrofluid being exchanged between HAC 101 and HDC 102. In this manner, a substantially continuous flow of batches of ferrofluid occurs in the closed-loop converter. This flow is utilized to induce electric current in an electric wire, as will be described hereinbelow.

Electricity conducting wires 110 and 111 are coiled around conduits 120 and 118, respectively. The magnetic particles flowing through these conduits should induce electric currents in wires 110 and 111, which are provided to loads 112 and 113. However, since the magnetic particles are aligned randomly (with respect to one another) in their carrier (whether a liquid or a gas, depending on the location in the converter and on the stage of the cycle), their net magnetic field is essentially zero. Under such circumstances no current will be induced in electric wires 110 and 111. In order to produce electric current, the magnetic particles must be aligned in such a way as to produce a non-zero net magnetic field moving through the coiled electric wires (110 and 111). This alignment is implemented by the use of magnetic rings 108 and 109, which are located so as to generate a

constant magnetic field at sections of the closed-loop converter surrounded by coil of wires and through which the ferrofluid and ferrogas flow.

Magnetic rings 108 and 109 are shown encircling conduits 118 and 120 in order to generate magnetic fields that will align the magnetic particles with their longitudinal axis substantially coinciding with the longitudinal axis of the conduits. In this way, the flow of the magnetic particles will produce a local non-zero magnetic field that induces an electric current in electric wires 110 and 111.

In order to further control the operating conditions within the converter, a reservoir container 103 is provided.

Reservoir container 103 is initially partially filled with ferrofluid, and it is used according to one of the following two scenarios:

(1) The ferrofluid contained in the reservoir container is utilized for cooling, per each cycle of operation of the converter, the ferromixture at the outlet of HDC, by opening its valve, concurrently after completing the first step of the cycle, whereby to release cold ferrofluid from the reservoir container 103 to the outlet of the HDC 102. The reservoir container is refilled with cold ferrofluid in each cycle of operation of converter, to cool the outlet of HDC 102 in the successive cycle.

(2) In order to cause the ferrofluid in HAC 101 to turn into gas, while flowing through the outlet valve 104 of HAC 101, it is essential to maintain a certain relationship between the temperature and the pressure of the ferrofluid on both sides of valve 104. Because of possible unstable ambient conditions, the relationship must be adjustable within some known operating range. The aforesaid relationship is maintained in the following way: if the temperature inside HAC 101 decreases, the pressure in HAC 101 must be reduced such that the boiling temperature of the ferrofluid in HAC 101 will be decreased as well, to allow it to boil at the lower temperature. The pressure in HAC 101 is reduced by reducing the overall pressure in the converter 100, by filling the reservoir container 103 with some of the ferrofluid. This is done by opening valve 117 only when the pressure in HDC 102 is higher than the pressure in the reservoir container 103. Likewise, when the temperature in HAC 101 increases, the pressure in HAC 101 must be increased as well, to maintain the aforesaid relationship. The required increase in this pressure is obtained by increasing the overall pressure in the main circuit of converter 100, by addition of at least some of the ferrofluid contained in the reservoir container 103. This is done by opening valve 117 only when the pressure in the reservoir container 103 is higher than the pressure in HDC 102, a situation that might occur essentially at any stage of an individual cycle of operation.

Normally, valve 117 should open or close in order to cool the ferromixture, as described hereinabove in connection with the first scenario. However, if there is a need to increase or to decrease the overall pressure in the converter 100, as described hereinabove in connection with the second scenario, then the second scenario will prevail; i.e., valve 117 will operate according to the second scenario, to assure that the converter 100 operates within the preferred operating range, and, therefore, that the converter maintains the highest efficiency possible for the given ambient conditions.

Referring to Fig. 2, valves 208, 202, 206, 210, 204 and 213 are mechanical one way valves, which open and close according to the pressure difference on both sides of the valve. Each one of these valves can be provided with a spring to close the valve when the pressure difference on it is essentially zero, or, alternatively, the spring can be chosen such that the valve will remain in the "closed" state as long as the counter (i.e., "opening") pressure exerted thereon is smaller than a predetermined value.

Still referring to Fig. 2, the activation of valves 207, 201, 209, 205 and 203 is controlled by a controller (mechanical or electronic, both not shown), which is configured to respond to corresponding input signals indicative of pressures and temperatures at the relevant locations in the converter. By 'relevant location' is meant the locations at which the value of the temperature, pressure, or both pressure and temperature, is measured to

activate the valves at the correct instants during each cycle of operation of the converter. There is a very large selection of commercially available pressure and temperature sensors (not shown), as well as valves and controllers, from which any person skilled in the art can choose for the purpose of the invention.

Fig. 2 schematically illustrates the converter according to a preferred embodiment of the present invention. For the purpose of simplifying the description of the operation of the converter, it is assumed that all the valves are initially in the "CLOSED" state and the converter contains ferrofluid and carrier gas at a predetermined ratio and quantities that depend on the dimensions of the converter 200, the ambient conditions, operation frequency and desired electrical output of the converter 200. An exemplary ratio is about 1:1. Container 217 is placed in a relatively cold place, for example, near the HDC, whereas the HAC is placed in the hotter place. Reservoir container 217 is initially and partially filled with ferrofluid and carrier gas at ambient temperature in the 1:1 ratio noted above.

Container 218 (a 'booster' container) is located between the outlet of HAC 101 (A2) and a midsection of HDC 102. Container 218 contains, in each cycle of operation of the converter 200, ferrofluid that is maintained under

pressure of carrier gas, for further 'boosting' the flow of ferrofluid/ferromixture from B2, as described in detail hereinbelow.

HAC 101 is shown divided into two sections, A1 and A2. Likewise, HDC 102 is shown divided into sections B1 and B2. A1 and A2 function to create conditions for an acceleration phase (of ferrofluid) inside 101. Likewise, B1 and B2 function to obtain an acceleration (of ferromixture) inside 102.

At the beginning of the electricity generating process, the carrier gas in A2 is at predetermined starting pressure. The starting pressure is such that for the effective temperature, which is the sum of the ambient temperature and the temperature rise due to the accumulated solar heat, the ferrofluid will turn from liquid into gas while passing from A2 to outlet conduit 220, and from container 218 to conduit 219. As heat starts to accumulate inside A2, the temperature of the ferrofluid and the gas inside A2 starts to increase, and therefore, the pressure inside A2 starts to increase. When the pressure in A2 reaches the predetermined starting pressure, valve 201 is opened. Simultaneously, valves 202 and 207, and thus valve 208, are opened as well, initiating a cycle of operation. As a result of the opening of these valves, some of the pressurized ferrofluid in A2 flows into 'booster' container 218 and another portion thereof flows as ferrogas into B1 through outlet conduit 220. Because the ferrogas in the outlet conduit 220 is at relatively high pressure and is 'injected' into the

elongate container B1 from outlet conduit 220, a compression force is exerted on the ferromixture contained therein. Under these conditions, temperature of B1 increases, which makes the heat dissipation phase from B1 to the heat sinkmore efficient.

When the ferrogas enters B1, it starts to condense to form a ferromixture with a relatively high content of gas, and as the mixture flows towards valve 206, the ferromixture further gradually condenses, and, therefore, the ferromixture at 206 will contain a lower portion of gas then at 202.

When the pressure in B1 is higher than the pressure in B2, valve 206 opens to allow the transfer of ferromixture from B1 to B2, thus increasing the pressure in B2. Valve 206 is one-way valve, which is automatically closed when the pressure in B2 is essentially equal to, or greater than, the pressure in B1. The closure of valve 206 does not permit ferromixture to return from B2 to B1. The closure of valve 206 sends a signal to the controller to close of valves 201 and 202.

As noted hereinbefore, valves 207 and 208 were opened to allow the pressure in container 218 to rise. When the pressure in booster container 218 becomes higher than the pressure in A2, valve 208 is closed, causing valve 207 to close as well.

Closing valve 206, at the instant mentioned before, causes the opening of valves 203, 204, 209 and 210. Therefore, the ferrofluid that is under high pressure in booster container 218 is expelled from 218 and, and as it passes from bosster container 218 to the booster conduit 219, the ferrofluid changes its phase from ferrofluid to ferrogas. The high pressure ferrogas travels at high velocity through booster conduit 219, and pushes the relatively cold ferromixture from B2 towards A1, through (now) opened valves 209, 210, 203, and 204. Because the ferrofluid flows from relatively narrower inlet conduit 214 into a much wider container A1, its temperature further decreases (which makes the heat absorption phase in A1 more efficient). While ferrofluid flows into A1, the pressure inside A1 increases and additional increase in this pressure is obtained while A1 absorbs external heat. At some point, the pressure in A1 will be higher than the pressure in A2, in which case, valve 213 is opened, to allow, thereby, ferrofluid to be transferred to A2. At another time, the pressure in A2 will tend to be higher than the pressure in A1, which will cause one-way valve 213 to close. The closure of valve 213 indicates the completion of one cycle of operation of the converter. The closure of valve 213 causes valves 203, 204, and 209 and 210, to close as well, and at the same time, the closure of valve 213 causes valves 201 and 207 to open, to start another cycle, essentially as described hereinabove.

Reservoir container 217, rings 222, 223 and 227, and wires 215, 216 and 226, function in the same way as container 103, rings 108 and 109, and wires 110 and 111 (Fig. 1).

Safety means are provided to prevent the occurrence of the following events:

1) The pressure in A2 increasing above the operating range. This is an indication that the ferrofluid/ferrogas/ferromixture circulates with a velocity that tends to increase to progressively high levels. If the increase of velocity is not interrupted on time, then the overall pressure in the converter will increase to dangerous levels. In order to prevent this from happening, when a predetermined threshold pressure is exceeded, a controller sends a signal to open valve 211 momentarily to permit hot ferrofluid to flow directly from A2 to B2. Of course, valve 211 can be used also for slowing down the operation of the converter, should the need arise for any reason, such as when there is a need for routine maintenance or to replace a malfunctioning part.

2) If valve 211 malfunctions, pressure safety valves 212 and 228 permit release of gas outside the converter, to reduce the pressure in A2 and/or in container 218, respectively.

The high velocity of flow of the ferrofluid/ferrogas in the converter may result in the creation of dangerous static electrical charges. In order to prevent the accumulation of such charges, it is essential that the relevant components of the converter be connected to the earth, to allow discharging charges to the earth. An exemplary connection is schematically shown in Fig. 2, by reference numeral 224.

In another embodiment of the invention, optical elements are provided to focus solar radiation inside the outlet conduit 201 and 209 (optical elements 201/1 and 209/1, respectively, in Fig. 2). The light is focused through a window in the wall of the conduit. The window is provided with an electrically activated shutter. The shutter opens when valves 201 and 209 open, and closes when these valves close. Such an optical arrangement will add additional heat to the ferrogas in the outlet conduits, increasing the temperature and pressure of the gas.

In another embodiment, the activated valve (201) connected to the first outlet of the HAC and the valve (209) connected to the outlet of the booster are each provided with an optical arrangement, (201/2) and (209/2), respectively, for collecting light rays and for focusing the collected light rays such as to raise the temperature of the ferrogas contained within the outlet conduit 220 and the booster conduit 219, respectively, for increasing the velocity of the magnetic particles that are suspended in the ferrogas.

The optical arrangement is arranged such that the focused light rays pass through the corresponding valve and the location of the corresponding focal point changes with the movement of the respective valve such that light rays are focused whenever the valve is in the "open" state, and dispersed otherwise.

The design of an appropriate optical system, which preferably includes a heliostat, is within the ability of skilled persons and will not be further described herein.

The high velocity of the magnetic particles carried by the ferrogas in conduits 219 and 220 might cause mutual erosion of both the magnetic particles and the conduits and valves through which the magnetic particles pass. A way of minimizing erosion is to assure that the magnetic particles pass in a straight line from valve 201 to valve 202, and from valve 209 to valve 210, and, optionally, by incorporating in each valve magnetic elements that will generate in the interior of the valves magnetic fields, such that the magnetic particles will be forced by the magnetic field to form a narrow beam while flowing through the middle of the opening of the valve. This way, there will be essentially no contact between the magnetic particles and 'sensitive' edges of the valves, and between the magnetic particles and the walls of the conduits.

B1 and B2 (i.e., the HDC) can be effectively cooled by spraying thereon water, and by rapid evaporation thereof, that is preferably made more efficient by utilizing wind. In co-pending Israeli Patent Application No. IL 159691, the inventor of the present invention describes an energy converter unit (a "sea wave converter") that converts the energy of sea waves and wind into electrical energy. The sea wave converter consists of a first wing ('wave wing'), to engage the sea waves, and a second wing ('wind wing') to engage the wind. The sea wave converter, the detail structure and functionality of which is described in co-pending Israeli Patent Application No. IL 159691, is schematically illustrated in Figs. 3 and 4, which are described hereinafter.

Referring to Figs. 3 and 4, the sea wave energy converter includes a first (i.e., a wave) wing 301 and a second (i.e., a wind) wing 401 (Fig. 4). Only the wave wing 301 is shown in Fig. 3, for simplicity. The wave energy converter comprises, in addition to the aforesaid two wings, a wing trailing edge supporting means 402, pivotable flap 403, to which a flap weight is connected (404), and pivot supporting means 405, for pivotly supporting the leading edge (the edge facing the wave side) of wing 401. Pivotable flap 403 comprises an airfoil 403/A and a hydrofoil 403/H sections, which form a fixed angle η. Wing 401 is longitudinally located along the wing 301, and it is structured to resemble a typical wing of an airplane and is intended to function as such. Wing 401 is preferably structured to be as

light as possible, such as by using light and resilient materials (metal and/or plastics) and, optionally, by leaving hollowed cavities therein, to obtain as much elevation force as possible. However, if desired, the mass of wing 401 can be made heavy enough to return wing 301 from any position to its rest (i.e., horizontal) position. The energy of the wind is translated, by use of wing 401, to an elevation force that is added to the force generated by the energy of the waves, which is obtained by use of wing 301. The stronger force, which is the sum of the wind force and wave force, displaces wing 301 more efficiently. The results of this is a larger electrical energy at the output of the converter.

In Fig. 3, reference numeral 300 denotes buoyancy that floats on the surface of the sea to support sleeve 304 and wing 301. Wing 301 is shown comprising a plurality of wing cells, such as wing cells 312, which form a honeycomb-like structure. Reference numeral 314 denotes a pivotable sleeve, which is rigidly connected to (wave) wing 301 and contains electricity generation means that generate electricity as a function of the displacement of wing 301, relative to the horizon, which is caused by the motion of waves. Each wing cell 312 has a wide opening 305 that is directed to a direction substantially perpendicular to the plane of the wing, such that, whenever wing 301 is in a rest, normal or horizontal, position, the wide openings of the wing cells face the water side and are fully soaked in the body of water. Each wing cell includes also a narrower,

elongate, passage (a 'vent' opening, 304), that connects the interior 310 of the wing cell to the atmosphere (306) in the opposite side of the wing. Therefore, whenever wing 301 is in horizontal position, the water 'pushes' the air locked in the interior 310 of the wing cells through the respective vent opening 304, whereby to allow to the interior 310 of each wing cell to be filled with water. Only four wing cells are shown in Fig. 3 (312), for simplicity. The honeycomb-like wing cells are arranged such that the closer the cells to the sleeve 314, the larger is their interior space, and therefore, the larger their water-holding capacity.

The energy converter of the present invention can be incorporated into the energy converter shown in Fig. 4 in a way that the HAC 101 is installed on the upper side 401 of the "wind wing" (401); i.e., the side normally facing the sun, and the HDC 102 is installed between the "wave wing" (301) and the "wind wing" (401), for utilizing the spray of the water, which surges upwards, essentially vertically, through the 'vent' openings 304 in the honeycomb-like wave wing, to cool the HDC 102 and, thus, the ferrofluid, ferromixture and/or ferrogas contained within it.

Analysis of the converter operated at first temperature (T1) of about 27 $^\circ C$, second temperature (T2) of about 20 $^\circ C$, and pressure in the system of about 0.5 atm., show that the efficiency of the converter is about 17%. However, after concentrating the sun's radiation by use of optical

arrangement, the theoretical efficiency of the converter was calculated to be about 37%. As a general guideline, the higher the temperature at which the ferrofluid can remain in its original state, the higher can be the maximum allowable temperature at which the system can operate, which allows even further improvement in the efficiency of the converter.

The aforesaid data are only preliminary results that were obtained based on theoretical analysis of the proposed structure of the converter, and using the first and the second laws of thermodynamics.

The above embodiments have been described by way of illustration only and it will be understood that the invention may be carried out with many variations, modifications and adaptations, without departing from its spirit or exceeding the scope of the claims.

CLAIMS

1. Converter for converting thermal energy into electrical energy by causing ferrofluid to circulate in said converter to induce electric current in coils of one or more electric wires, comprising:

h) A main circuit, comprising:

a.1) A Heat Absorbing Container (HAC), having an inlet that is connected to a first end of an inlet conduit, a first outlet that is connected to a first end of an outlet conduit, and having a first cross-sectional area, said inlet and first outlet conduits and said HAC initially containing a ferrofluid and carrier gas, said HAC absorbing heat energy from an external heat source to heat said ferrofluid and said carrier gas to a first temperature (T1) and first pressure (P1), said outlet and inlet conduits having a cross-sectional area smaller then said first cross-sectional area;

a.2) An elongate Heat Dissipating Container (HDC), having an inlet, connected to the second end of said outlet conduit, and an outlet connected to the second end of said inlet conduit, said HDC having a second cross-sectional area smaller than said first cross-sectional area, said HDC is initially filled with ferrofluid and carrier gas and said HDC dissipates heat to an external heat sink to cool the ferrofluid and carrier gas contained therein to a second temperature (T2), lower than T1, and a second pressure (P2), the ferrofluid in said HAC passes to said HDC, through said outlet conduit, in the form of ferrogas

whenever P1 equals a predetermined value higher than P2, said ferrogas carrying magnetic particles from said HAC to said HDC in the first step of the operational cycle of said converter, said ferrogas gradually condensing, while passing through said elongate HDC, until at the outlet of said HDC, it essentially condense to be entirely ferrofluid; said ferrofluid being returned from said HDC to said HAC to complete a second step of said cycle and the entire cycle;

b) A reservoir container , connected by a conduit to the outlet of said HDC, for regulating the operating conditions in said converter such that the relationship between T1 and P1 assures that said ferrofluid remains in the liquefied phase inside said HAC and changes from ferrofluid to ferrogas while passing from said HAC to said outlet conduit, and such that the relationship between T2 and P2 assures full condensation of the ferrogas at the outlet of said HDC, by allowing exchange of ferrofluid stored in said reservoir container with said main circuit such as to lower, or to raise, as required, the overall pressure in said main circuit, said reservoir container being utilized also for further cooling, in each cycle of operation of said converter, the ferrofluid at the outlet of said HDC;

c) Activated valves, for timely opening and closing the first outlet of said HAC and the outlet of said HDC and inlet/outlet of said reservoir container;

d) A first mechanical one-way valve, connected at the inlet of said HAC for allowing ferrofluid to flow only in a direction from the outlet of said HDC to the inlet of said HAC, as a result of a pressure exerted thereon by the flow of ferrofluid, and a second mechanically activated one-way valve, connected at the inlet of said HDC for allowing ferrogas to flow only in a direction from the first outlet of said HAC to the inlet of said HDC, as a result of a pressure exerted thereon by the flow of ferrogas;

e) Control means, for timely operating said activated valves;

f) Magnetic field generation elements, for generating magnetic fields in the area of sections of said inlet and first outlet conduits to align said magnetic particles in said sections such as to cause alignment of the magnetic fields generated by said particles while moving through said sections of said conduits; and

g) Electricity conducting wires, coiled around sections of said inlet and outlet conduits, wherein electric current is induced in the coils of said wires in response to said magnetic field generated by said moving particles.

2. Converter according to claim 1, further comprising a booster container and a booster conduit; wherein said booster container comprises a booster inlet connected to a second outlet of the HAC and a booster outlet; and wherein a first end of said booster conduit is connected to said booster

outlet and a second end of said booster conduit is connected to a midsection of said HDC; wherein the ferrofluid passes from the HAC to the booster container and it changes phase from ferrofluid to ferrogas while passing from said booster container to said booster conduit, and the ferromixture arriving at the HDC at said second end of said booster conduit boosts the flow of said ferrofluid, which exists in said HDC, to flow through the inlet conduit towards said HAC, said second outlet and said booster outlet are each controlled by a valve that is controlled by the controller, and said midsection is provided with a mechanical one-way valve that opens as a result of the pressure exerted thereon by said ferromixture.

3. Converter according to claim 1, in which the HAC includes a third outlet, said third outlet being a "slowdown"/"shutdown" outlet, and the HDC includes a second inlet, said inlet being a "slowdown"/"shutdown" inlet; said second inlet being connected to said third outlet by a "slowdown"/"shutdown" conduit, for allowing, whenever required, slowing down of a velocity of flow of the circulating ferrofluid, ferrogas and ferromixture, to maintain said velocity in a desired operating range, or, if desired, to completely stop the circulation of said ferrofluid/ferrogas and, thus, the operation of the converter; said slowing down and stopping are accomplished by decreasing the difference between the pressure inside said HAC (P1) and the pressure inside said HDC (P2), by opening,

momentarily or continuously, respectively, said third outlet, whereby to decrease the pressure in said HAC (P1) and, thus, the velocity of the flow of the ferrogas inside the outlet conduit of said HAC and inside the booster conduit, said "slowdown"/"shutdown" outlet being controlled by an activated valve that is controlled by the controller.

4. Converter according to claim 3, in which the slowdown/shutdown outlet is preferably located closer to the outlet of the HAC than to its inlet, and the slowdown/shutdown inlet is preferably located closer to the outlet of the HDC than to its inlet.

5. Converter according to claim 3, in which the HAC is divided into two longitudinal sections, A1 and A2, and the HDC is divided into two sections, B1 and B2, A1 and B1 being inlet sections of said HAC and HDC, respectively, whereas A2 and B2 being outlet sections of said HAC and HDC, respectively, said division being utilized for obtaining an internal acceleration of the ferrofluid and ferromixture inside said HAC and HDC, respectively, wherein each of the two corresponding sections are connected by a mechanical one-way valve that opens as a result of force exerted thereon by flow of ferrofluid and/or ferromixture, the mechanical one-way valves allow ferrofluid and/or ferromixture to flow only in a direction which conforms to the circulation direction.

6. Converter according to claim 2, in which the first outlet conduit of the HAC and the booster conduit are provided with an optical arrangement for collecting light rays and for focusing the collected light rays such as to raise the temperature of the ferrogas contained within said conduit; said rise in temperature causing to increase the velocity of the magnetic particles that are suspended in said ferrogas.

7. Converter according to claim 6, in which the optical arrangement comprises a window that is formed in the walls of the outlet and booster conduits, near the corresponding activated valves.

8. Converter according to claim 7, in which the window comprises an activated shutter, which opens and closes when the first outlet and the booster conduit's outlet open and close.

9. Converter according to claim 6, in which the optical arrangement comprises a heliostat.

10. Converter according to claim 2, in which the activated valve connected to the first outlet of the HAC and the activated valve connected to the booster conduit are each provided with an optical arrangement for collecting light rays and for focusing the collected light rays such as to raise the temperature of the ferrogas contained within the outlet conduit

and the booster conduit, respectively, for increasing the velocity of the magnetic particles that are suspended in said ferrogas; said optical arrangement is arranged such that the focused light rays pass through the corresponding valve and the location of the corresponding focal point changes with the movement of the respective valve such that light rays are focused whenever said valve is in the "open" state, and dispersed otherwise.

11. Method for converting thermal energy into electrical energy by causing magnetic particles to circulate in a closed-loop passage, which includes a HAC, elongate HDC, inlet conduit that connects the input of said HAC to the output of said HDC, and outlet conduit that connects the outlet of said HAC and the inlet of said HDC, and by utilizing the cycling magnetic particles to induce electric current in coiled electric wires, comprising:

a) Absorbing heat by said HAC, from an external heat source, which is filled with ferrofluid and carrier gas, to increase the pressure inside said HAC;

b) Commencing a first step of a cycle of operation of the convertion, by permitting the high pressurized ferrofluid to pass, through an outlet conduit, towards said HDC, while changing phase in said outlet conduit from ferrofluid to ferrogas; said magnetic particles are suspended in, and carried by, said ferrogas to said HDC;

c) Completing said first step by storing the high pressurized ferrogas, in the form of ferromixture, in said HDC;

d) Commencing a second step of said cycle by utilizing said stored pressurized ferromixture in said HDC to push already, or previously, condensed ferrogas to flow forwards as ferrofluid and return from said HDC to said HAC, while causing said ferrogas to condense in the HDC as it flows through said HDC, whereby to complete said second step and the entire cycle;

e) Commencing a new, subsequent, cycle of operation, by repeating steps a) to d); and

f) In each cycle, aligning said magnetic particles while they pass through sections of the inlet and outlet conduits, around sections of which electricity conducting wires are coiled, so as to cause said magnetic particles to induce electric current in said coiled electric wires.

12. Method according to claim 11, further comprising utilization of a booster container and a booster conduit; wherein said booster container comprises a booster inlet connected to a second outlet of the HAC and a booster outlet; and wherein a first end of said booster conduit is connected to said booster outlet and a second end of said booster conduit is connected to a midsection of said HDC; wherein the ferrofluid passes from the HAC to the booster container and it changes phase from ferrofluid to ferrogas

while passing from said booster container to said booster conduit, and the ferromixture arriving at the HDC at said second end of said booster conduit boosts the flow of said ferrofluid, which exists in said HDC, to flow through the inlet conduit towards said HAC, said second outlet and said booster outlet are each controlled by an activated valve that is controlled by the controller, and said midsection is provided with a mechanical one-way valve that opens as a result of the pressure exerted thereon by said ferromixture.

13. Method according to claim 11, wherein the HAC includes a "slowdown"/"shutdown" outlet, and the HDC includes a "slowdown"/"shutdown" inlet; said second inlet being connected to said third outlet by a "slowdown"/"shutdown" conduit, for allowing, whenever required, slowing down of a velocity of flow of the circulating ferrofluid, ferrogas and ferromixture, to maintain said velocity in a desired operating range, or, if desired, to completely stop the circulation of said ferrofluid/ferrogas; said slowing down and stopping are accomplished by decreasing the difference between the pressure inside said HAC (P1) and the pressure inside said HDC (P2), by opening, momentarily or continuously, respectively, said outlet, whereby to decrease the pressure in said HAC (P1) and, thus, the velocity of the flow of the ferrogas inside the outlet conduit of said HAC.

14. Method according to claim 13, wherein the slowdown/shutdown outlet is preferably located closer to the outlet of the HAC than to its inlet, and the slowdown/shutdown inlet is preferably located closer to the outlet of the HDC than to its inlet.

15. Method according to claim 11, further comprising dividing the HAC into two longitudinal sections, A1 and A2, and the HDC into two sections, B1 and B2, A1 and B1 being inlet sections of said HAC and HDC, respectively, whereas A2 and B2 being outlet sections of said HAC and HDC, respectively; said division being utilized for obtaining an internal acceleration of the ferrofluid and ferromixture inside said HAC and HDC, respectively, wherein the internal flow of the ferrofluid and ferromixture are in the direction of the circulation, each of the two corresponding sections are connected by a mechanical one-way valve that opens as a result of force exerted thereon by flow of ferrofluid and/or ferromixture, the mechanical one-way valves allow ferrofluid and/or ferromixture to flow only in a direction which conforms to the circulation direction.

16. Method according to claim 12, further comprising using optical arrangement for collecting light rays and for focusing the collected light rays such as to raise the temperature of the ferrogas inside the outlet conduit of the HAC and inside the booster conduit and, thus, to increase

the velocity of flow of the magnetic particles that are suspended in said ferrogas.

17. Method according to claim 16, wherein the optical arrangement is provided with a window that is formed in the walls of the outlet and booster conduits, near the outlets of the HAC and booster container.

18. Method according to claim 17, wherein the window is provided with an activated shutter, which opens and closes when the first outlet and the booster conduit's outlet open and close.

19. Method according to claim 18, wherein the optical arrangement comprises a heliostat.

20. Method according to claim 12, in which the activated valve connected to the first outlet of the HAC and the activated valve connected to the booster conduit are each provided with an optical arrangement for collecting light rays and for focusing the collected light rays such as to raise the temperature of the ferrogas contained within the outlet conduit and the booster conduit, respectively, for increasing the velocity of the magnetic particles that are suspended in said ferrogas; said optical arrangement is arranged such that the focused light rays pass through the corresponding valve and the location of the corresponding focal point

changes with the movement of the respective valve such that light rays are focused whenever said valve is in the "open" state, and dispersed otherwise.

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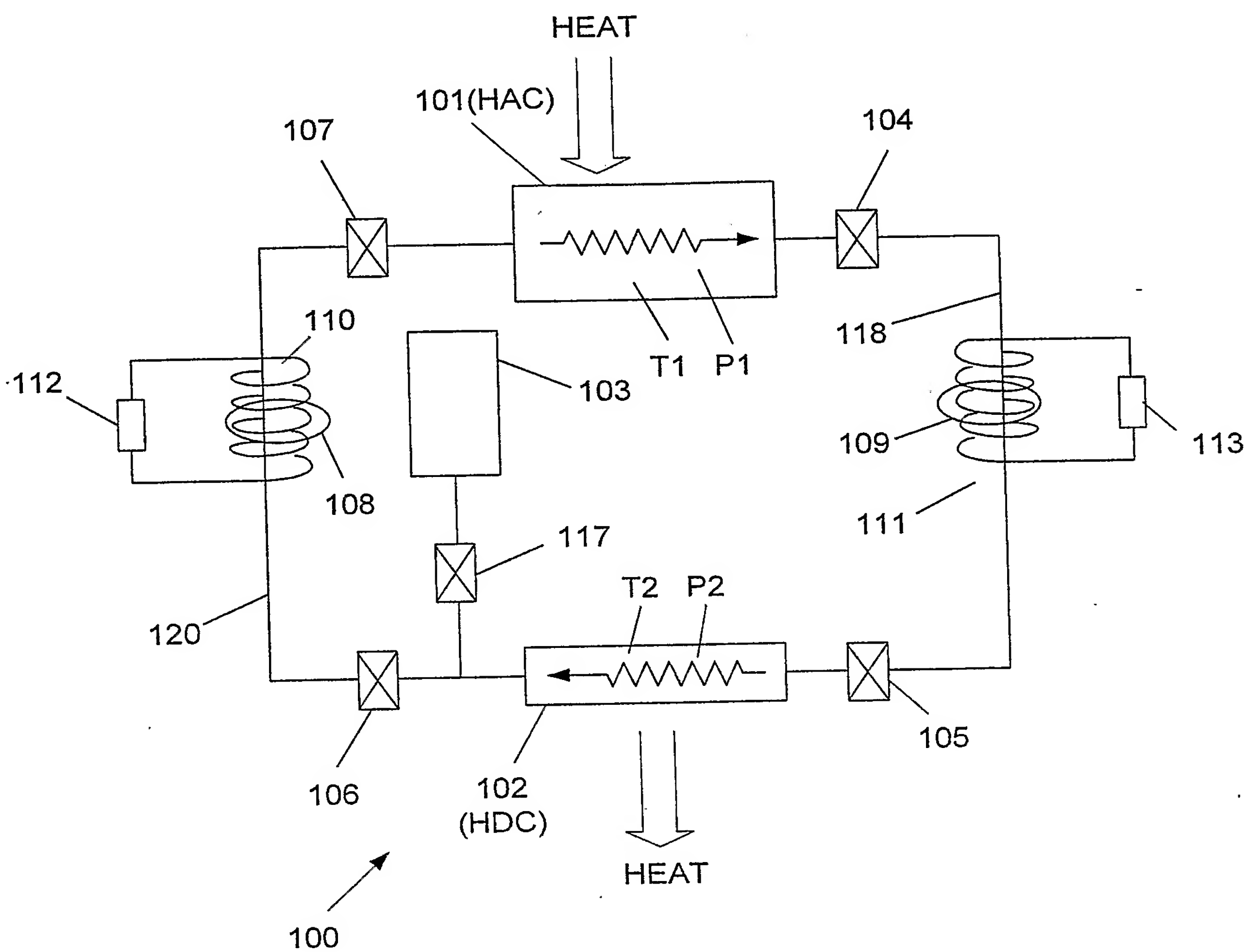
HEAT
101(HAC)
107
104
110
118
112
103
T1
P1
109
113
108
111
117
T2
P2
120
105
106
102
(HDC)
HEAT
100

Fig. 1

17110/04
HAIM MORGENSTEIN

Four Sheets of Drawings
Sheet No. 2

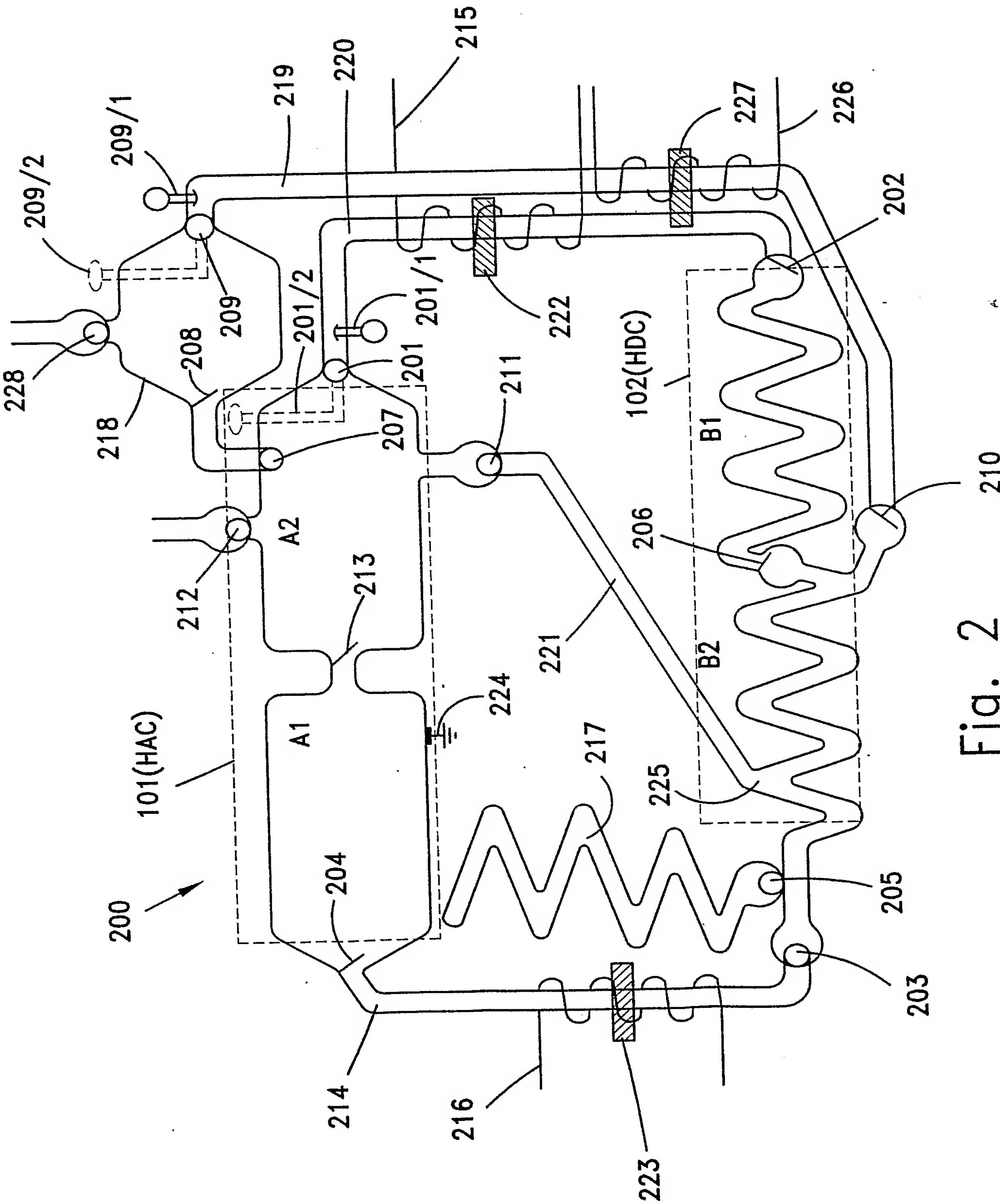

Fig. 2

17110/03
HAIM MORGENSTEIN

Four Sheets of Drawings
Sheet No. 3

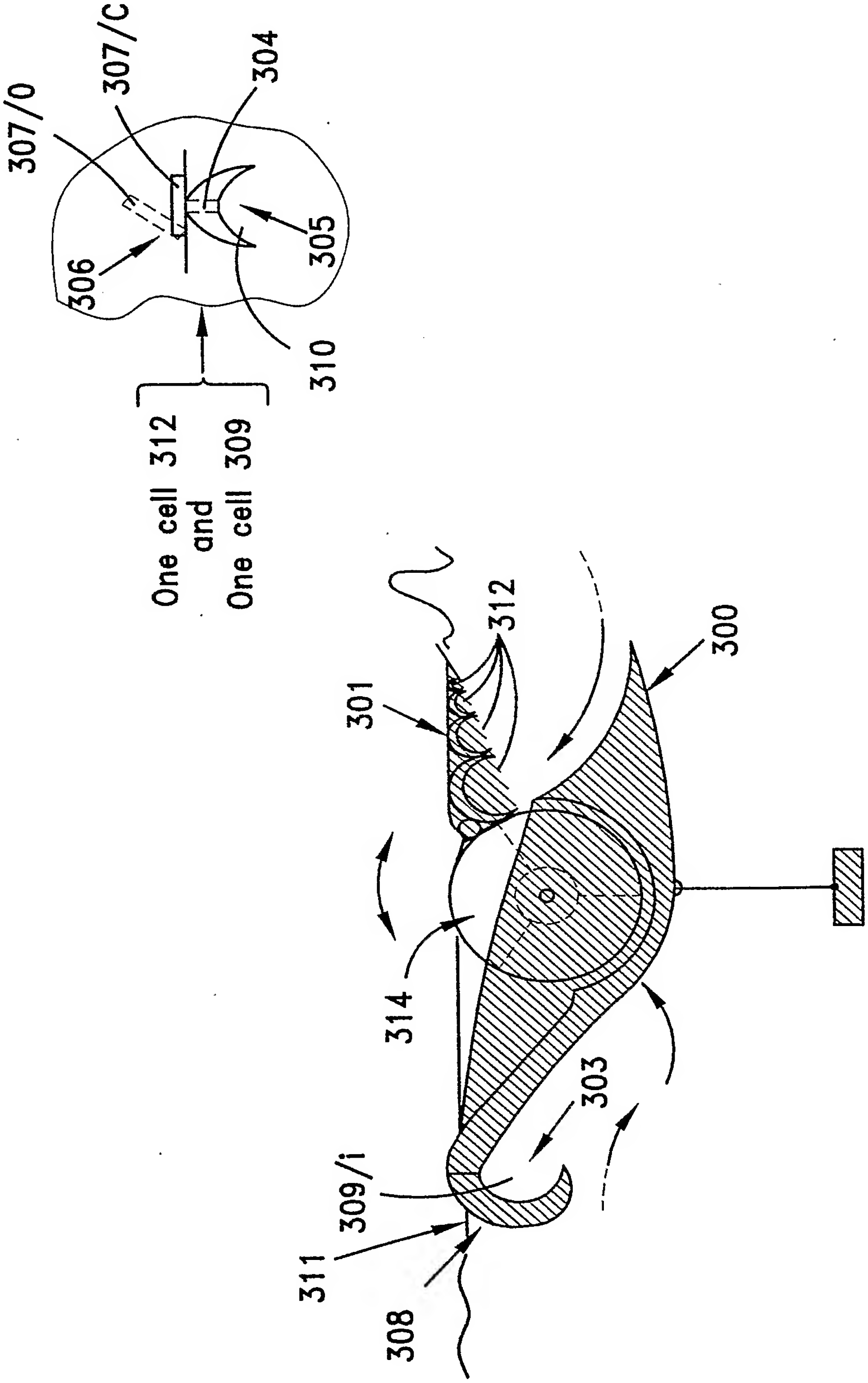

Fig. 3

17110/03
HAIM MORGENSTEIN

Four Sheets of Drawings
Sheet No. 4

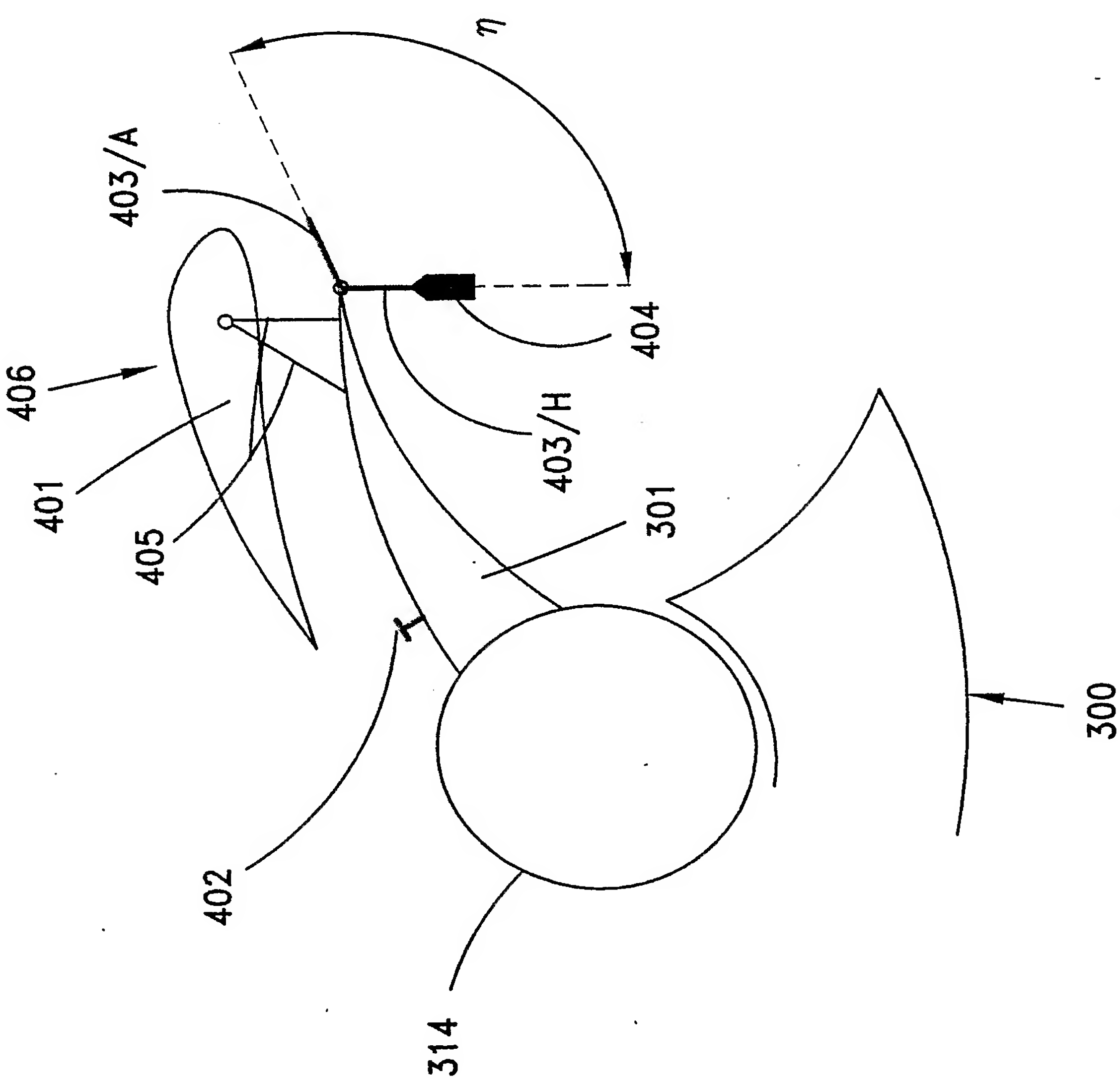

Fig. 4